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A Relation Between the CMB Temperature, the Hydrogen Ionisation Energy, and Fundamental Constants

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Status: Numerical observation. No theoretical derivation offered.
Consistent with CODATA 2018 and Fixsen (2009). Not submitted for publication.

Abstract

We report the following numerical observation. The temperature of the Cosmic Microwave Background satisfies, to within the measurement uncertainty of Fixsen (2009):

$$\boxed{T_{\mathrm{CMB}} \;=\; \frac{m_e^2\, c^2\, \alpha^2}{\pi\, e^3\, m_p\, k_B}} \tag{1}$$

where m_e is the electron mass, m_p is the proton mass, c is the speed of light, α is the fine-structure constant, k_B is the Boltzmann constant, and $e = 2.71828\ldots$ is Euler's number.

T_{computed}	$= 2.725434$ K
T_{CMB} (Fixsen 2009)	$= 2.725480 \pm 0.000570$ K
Error	$= 0.0017\%$
Within measurement uncertainty	Yes

The formula involves only well-known physical constants. No factorial, no correction term, no ad hoc parameter. No physical interpretation is offered.

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1 Background

The temperature of the CMB, $T_{\mathrm{CMB}} = 2.72548 \pm 0.00057$ K (Fixsen 2009), is a fundamental cosmological observable. Its value is set by the physics of recombination and has no known derivation from atomic constants alone.

In a previous preprint [?], we reported that $T_{\rm CMB}$ can be expressed to 0.0002% using the Heisenberg-Landauer equilibrium condition at the length scale $a_0 \cdot 5!$, with a correction factor $(1+\pi\alpha/4)$. While numerically more precise, that formula contained two unexplained ingredients (5! and the correction term).

Here we report a cleaner relation involving only standard physical constants.

2 The Observation

Consider the dimensionless ratio:

$$\frac{E_{\rm ion}({\rm H})}{k_B\, T_{\rm CMB}} \;=\; \frac{m_e c^2 \alpha^2/2}{k_B\, T_{\rm CMB}} \;=\; 57930.17 \tag{2}$$

where $E_{\rm ion}({\rm H}) = m_e c^2\alpha^2/2 = 13.6057$ eV is the hydrogen ionisation energy. We observe that:

$$\frac{m_p}{m_e} \cdot \frac{\pi}{2} \cdot e^3 \;=\; 57931.14 \tag{3}$$

The ratio of these two quantities is 0.99998, differing by 0.0017%. This gives equation (??) directly:

$$T_{\rm CMB} \;=\; \frac{E_{\rm ion}({\rm H})}{k_B} \cdot \frac{2}{(m_p/m_e)\,\pi\, e^3} \;=\; \frac{m_e^2\, c^2\, \alpha^2}{\pi\, e^3\, m_p\, k_B} \tag{4}$$

Quantity	**Value**	**Source**
$T_{\rm CMB}$ (formula)	2.725434 K	This work
$T_{\rm CMB}$ (measured)	2.725480 ± 0.000570 K	Fixsen 2009
Error	0.0017%	—
Within uncertainty	Yes ($\lvert\Delta T\rvert = 0.000046$ K)	—
$E_{\rm ion}/(k_B T_{\rm CMB})$	57930.17	CODATA 2018
$(m_p/m_e)\cdot(\pi/2)\cdot e^3$	57931.14	CODATA 2018

3 What the Formula Contains

Equation (??) contains:

- $m_e^2 c^2 \alpha^2/2 = E_{\rm ion}({\rm H})$: the hydrogen ionisation energy — the fundamental atomic energy scale.
- $m_p/m_e = 1836.15$: the proton-to-electron mass ratio — a dimensionless number of unknown theoretical origin.
- π: the geometric constant.
- $e^3 = 20.086$: the cube of Euler's number. **We have no physical explanation for the appearance of e^3 here.** It is not derived; it is observed numerically.

The formula does *not* contain: the gravitational constant G, the Planck length, the Hubble constant, or any cosmological parameter. It connects the CMB temperature directly to atomic physics.

4 Honest Assessment

We do not claim a causal or physical connection. Three interpretations are possible:

1. This is a numerical coincidence of no deeper significance.
2. There exists an unknown principle relating the CMB temperature to atomic energy scales via the proton-to-electron mass ratio.
3. The current measurement precision of T_{CMB} (± 0.00057 K, i.e. $\pm 0.02\%$) is insufficient to determine whether the agreement is exact.

We note that the dimensionless ratio $E_{\mathrm{ion}}(H)/(k_B T_{\mathrm{CMB}}) \approx 57930$ has a known physical significance: it governs the recombination epoch in standard cosmology. The epoch of recombination occurs when this ratio reaches approximately 45000–60000. The formula may therefore be encoding a known cosmological relationship in a compact form, rather than revealing new physics.

The observation is testable: the next generation of CMB temperature measurements (e.g. PIXIE, LiteBIRD) will reduce the uncertainty on T_{CMB} by one to two orders of magnitude, allowing a definitive test.

5 Summary

We observe that the CMB temperature satisfies:

$$\boxed{T_{\mathrm{CMB}} \;=\; \frac{m_e^2\, c^2\, \alpha^2}{\pi\, e^3\, m_p\, k_B} \;=\; 2.725434 \text{ K}} \tag{5}$$

to within the measurement uncertainty of Fixsen (2009). The formula uses only m_e, m_p, c, α, k_B, π, and e. No theoretical derivation is offered. This is reported as a numerical observation.

References

[1] D. J. Fixsen, "The Temperature of the Cosmic Microwave Background," *ApJ* **707**, 916 (2009). DOI: 10.1088/0004-637X/707/2/916

[2] CODATA 2018: $T_{\mathrm{CMB}} = 2.72548(57)$ K; $\alpha = 7.2973525693(11) \times 10^{-3}$; $m_p/m_e = 1836.15267343(11)$.

[3] J. Brindel, "A Derivation of the CMB Temperature from Atomic Constants, the Heisenberg Uncertainty Principle, and the Landauer Limit," Zenodo (2026). DOI: 10.5281/zenodo.18833947

[4] J. Brindel, "A Perturbative Series for the Proton-to-Electron Mass Ratio," Zenodo (2026). DOI: 10.5281/zenodo.18693489

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